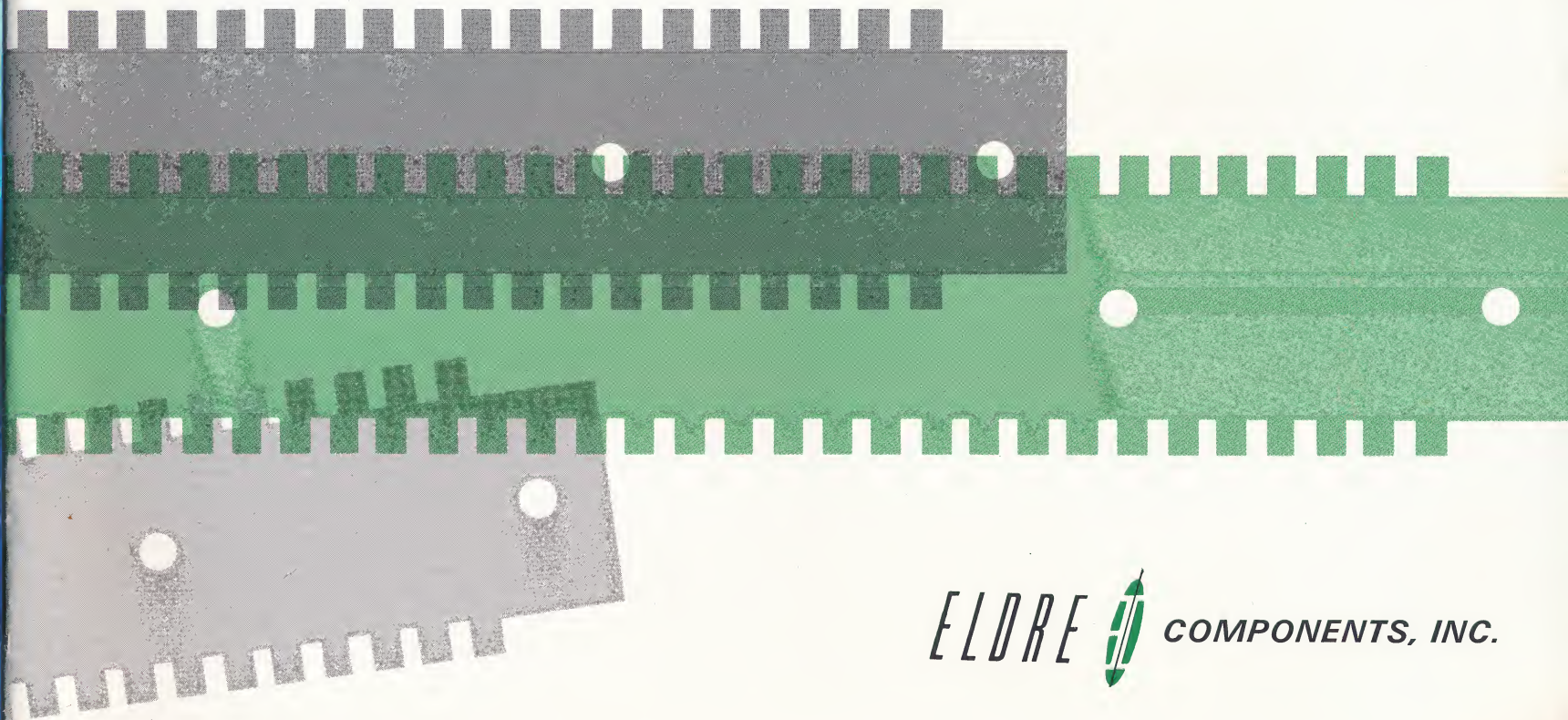
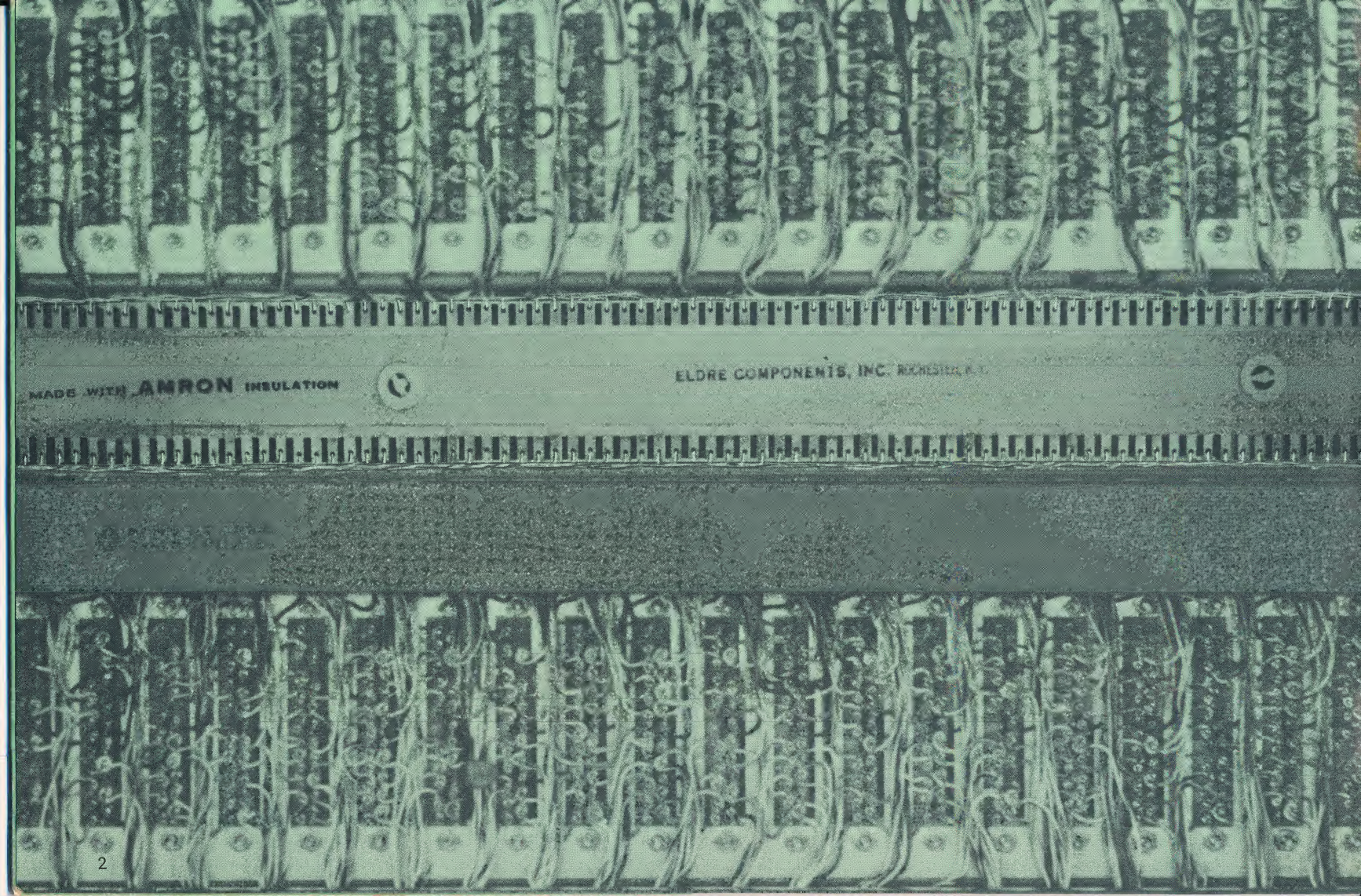


Laminated and Molded Bus Bars for Power Distribution

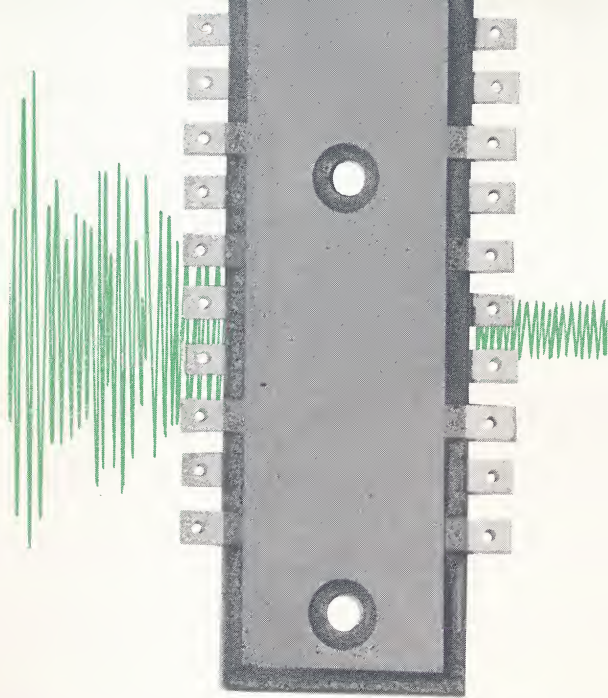


ELDRE  *COMPONENTS, INC.*



MADE WITH **AMRON** INSULATION

ELDRE COMPONENTS, INC. ROCHESTER, N. Y.



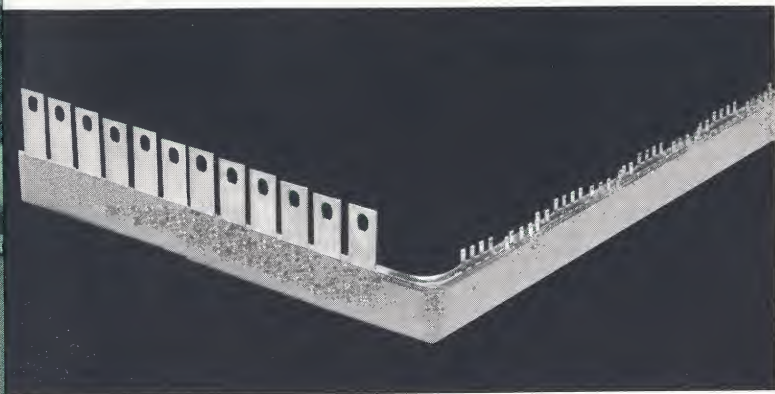
introduction

Here is a new concept in power or signal distribution—a laminated bus bar designed for noise reduction common in high density electronic assemblies. Now, in one compact space-saving unit, a laminated and molded bus bar—layers of flat conductors, each insulated with AMRON® insulation—that can be installed in any system and connected where needed.

It is the purpose of this bulletin to acquaint the design engineer with the advantages of a laminated bus bar for power distribution. Data and basic formulae are included to assist the mechanical and electrical engineers to design or specify an Eldre bus system for a particular application.

Eldre's laminated bus bar approach to power distribution offers—

- effective noise reduction in high-speed electronic systems.
- minimum inductance and resistance with high capacitance, eliminating extra components.
- the use of any type of termination on bus conductors.
- the possibility of utilizing bus system to replace wire harnesses.
- ease of assembly and connection.
- the conservation of valuable space allowing greater latitude of design.
- reduction in inventory and testing requirements.
- a superior ground and shield technique over conventional wiring.
- error-free wiring and economical maintenance by simplification of trouble-shooting techniques.

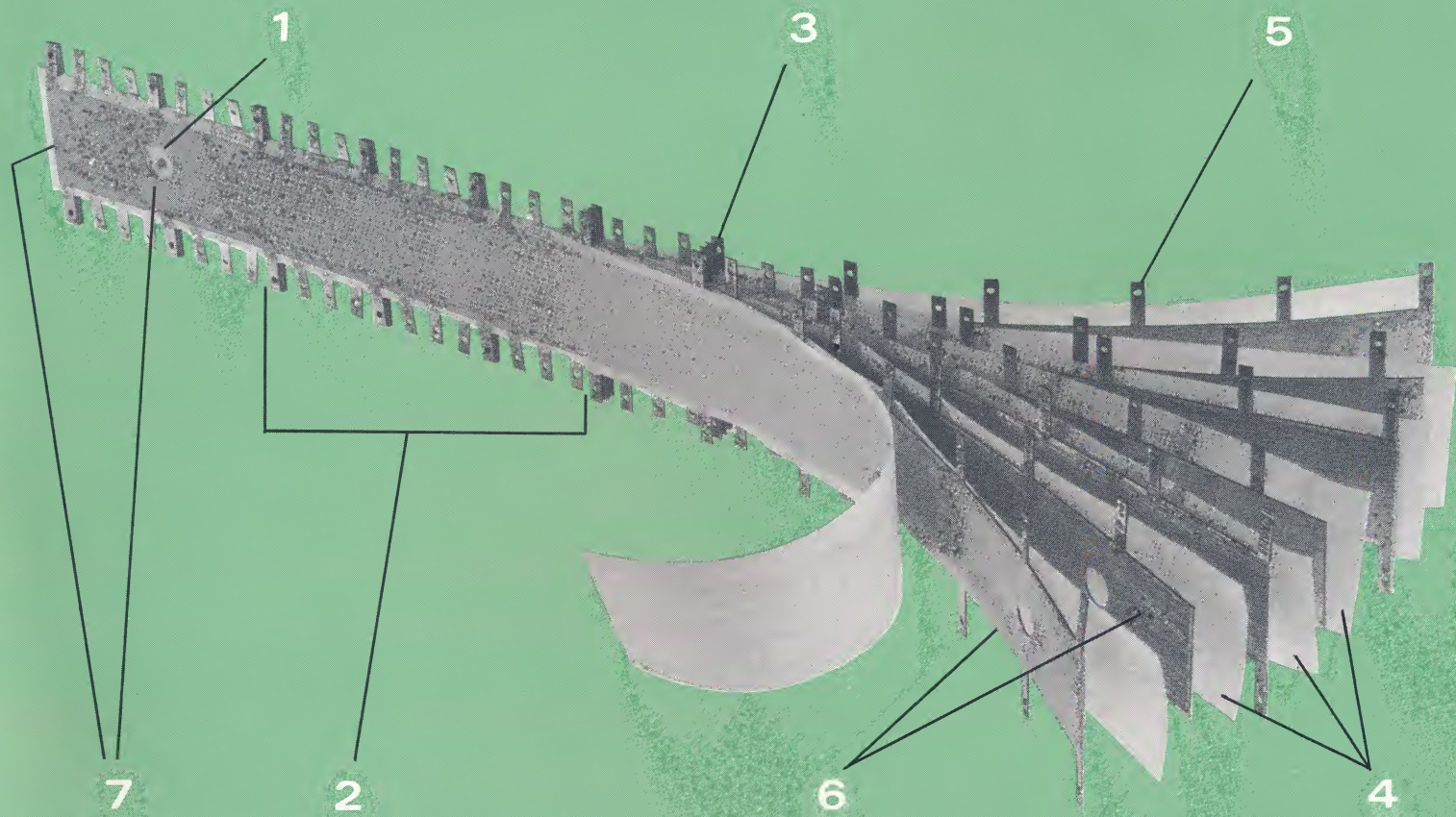


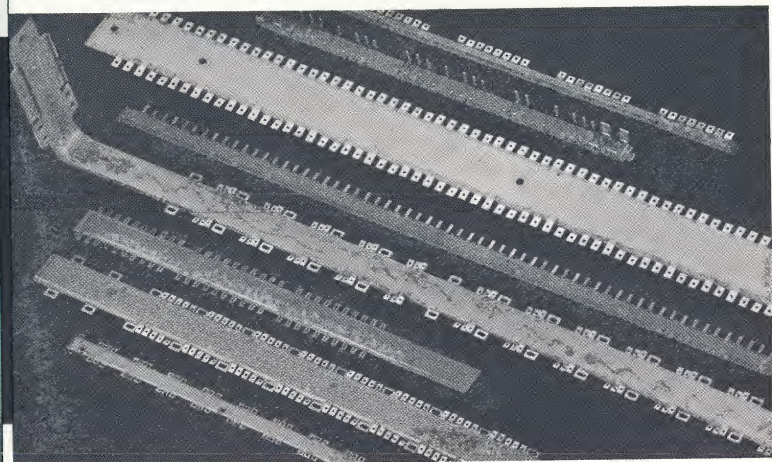
description of the Eldre Bus Bar

The ELDRE BUS consists of flat conductors isolated from each other with AMRON and molded into a sealed multi-conductor unit. The number of conductors or levels, the type and number of terminals, the size and finish of the conductor material, and the dielectric strength required depend upon the application. Edges are sealed forming a neat compact assembly.

Any number and type of terminals can be specified. A complete bus system with bends can be designed to fit into any cabinet. Custom made or off-the-shelf, ELDRE bus bars are made to meet your strict electrical and mechanical requirements.

- (1) Insulated mounting holes, sealed with AMRON insulation, are optional means for mounting bus bars.
- (2) Each conductor has terminations, as specified, at repetitive points to meet individual requirements.
- (3) Ground shields with common terminals in each repetitive section. Each power conductor can be shielded for noise control and isolation.
- (4) AMRON insulation—dielectric strength, thickness, and spacing to your specification.
- (5) Any type of termination can be designed into the bus.
- (6) Flat conductors are designed to your requirements—length, width, thickness, number and finish of conductors, and grounds.
- (7) All edges including the mounting holes are sealed to eliminate shorting from outside foreign matter.





basic design concept

High-speed, solid-state circuits demand greater attenuation of electrical noise. It is important that power distribution circuits be designed and placed with reference to minimum noise pickup—a common source of pickup is switching circuits. In addition, because transistorized equipment requires relatively high currents with low voltages in contrast to the voltage requirements for equivalent vacuum tube circuits, it is essential that dc power distribution lines have a minimum of inductance and resistance.

Resistance can be reduced by increasing the cross sectional area of a conductor. However, a large increase in conductor size will have only a slight affect on the inductance.

To obtain minimum, effective inductance conductors must be placed close together. In this manner, the magnetic fields around each conductor, when 180° out of phase, would tend to cancel and reduce a possible source of noise. Twisted pairs of wire have been used to achieve this affect—however, a twisted pair of wires has, as can be noted on the accompanying chart, (page 5) more inductance than a laminated distribution bus bar. In addition, note on the charts, that the #18 twisted wire and the corresponding bus bar have the same circular mil area.

Since each flat conductor in a laminated bar can be surrounded with ground shields to further reduce stray electrical fields, the laminated bus is even more desirable for power distribution. Moreover, the laminated bus bar design permits maximum allowable capacitance between adjacent conductors, thereby reducing and suppressing undesirable voltages, pulses, and noise.

Thus research has given us a new concept in power distribution—The ELDRE Laminated Bus Bar.

*resistance, inductance, and capacitance comparisons**

TWISTED WIRE



#10 AWG WIRE (SOLID)—36 inches in length
insulation thickness (approx.) = .030 inch
cond. area = .00815 in.² R_{dc} (calc.) = .006 ohm

Freq (cps)	R_{ac} (ohms)	L (μ hys)	C (pfds)
10^3	0.0109	0.70	< 100
10^6	0.078	0.464	53.6
10^7	0.160	0.478	48.1

#18 AWG WIRE (STRANDED)—36 inches in length
insulation thickness (approx.) = .015 inch
cond. area = .001276 in.² R_{dc} (calc.) = .038 ohm

Freq (cps)	R_{ac} (ohms)	L (μ hys)	C (pfds)
10^3	0.0524	0.8	< 100
10^6	0.275	0.557	57.3
10^7	1.3	0.540	52.0

ELDRE BUS BAR



ELDRE BUS BAR—36" long x 1.5" wide x .010" thick
insulation thickness = .006 inches AMRON #4
cond. area = .015 in.² R_{dc} (calc.) = .0032 ohm

Freq (cps)	R_{ac} (ohms)	L (μ hys)	C (pfds)
10^3	0.012	0.20	6400.
10^6	0.027	0.0129	6085.
10^7	0.079	0.0120	7480.

ELDRE BUS BAR—36" long x .125" wide x .006" thick
insulation thickness = .006 inches AMRON #4
cond. area = .00125 in.² R_{dc} (calc.) = .038 ohm

Freq (cps)	R_{ac} (ohms)	L (μ hys)	C (pfds)
10^3	0.048	0.3	700.
10^6	0.137	0.0738	678.
10^7	0.494	0.0614	667.

*Actual measurements: 1 kc made with a Rohde and Schwarz precision L-C Bridge, Type LCB, BN620; 1mc and 10mc measurements were made with a Siemens-Halske precision bridge, Model 3R218A

mechanical design information

To be able to manufacture a distribution bus, we must know how many conductors will be needed and the cross sectional area of these conductors. The terminations used and their position on the conductors are predicated upon the mechanical requirements. Total length, width and thickness, number of terminations and number of conductors are established by the application.

For best results, insulation overlap should be at least equal to the overall thickness of the bus. For instance, if there are four .010" thick conductors in a bus bar and AMRON #4 is used for the unit, the overall thickness will be .070" (see Figure 1).

Five laminations of AMRON are required for a four conductor bus bar. The thickness of bus bar = $4 \times .010" + 5 \times .006" = .070"$. Thus all edges of insulation overlap will be .070" (see Figure 1.)

The method of mounting the bus system into the cabinet or unit can be accomplished by two basic methods. One, the use of



bracket arrangements; the other, through insulated holes in the conductor.

Recommended method of mounting the laminated bus is through holes prestamped in each of the conductors (see Figure 1). After the assembly and molding of the bus bar, holes are covered with AMRON and are then pierced for mounting.

The width of the conductors should be at least three times the thickness of the bus bar. The length of the termination is determined by the requirement and the amount of room available while bearing in mind the insulation overlap formula.

If solder type terminations are desired, the conductor should be made of half-hard copper. The conductors may be plated (tin, silver, gold) to meet specifications. If a wrapped wire (see Figure 2) termination is desired, the conductors should be made of hard copper or copper alloys such as brass or beryllium copper. The same plating as above can be considered for these conductors.

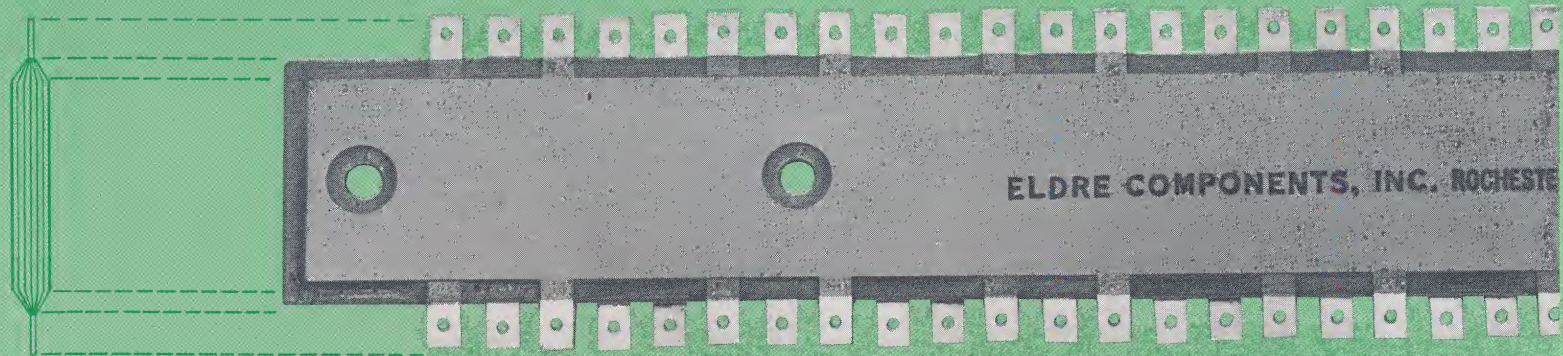


Figure 1

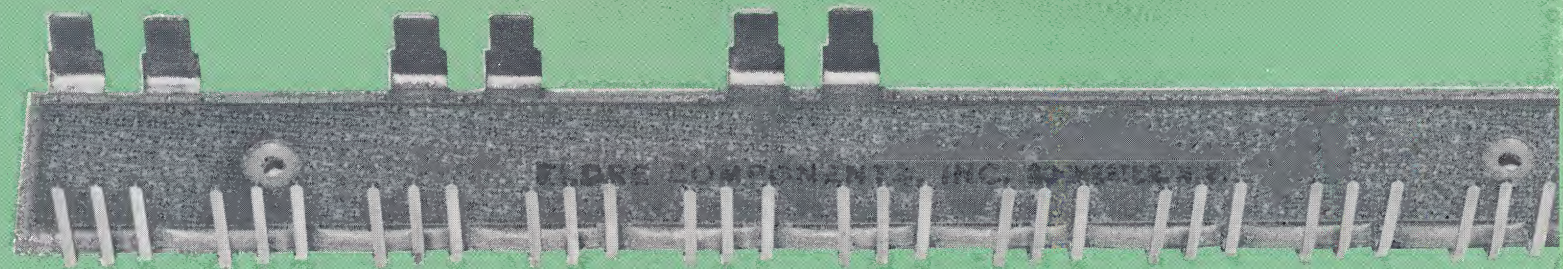


Figure 2

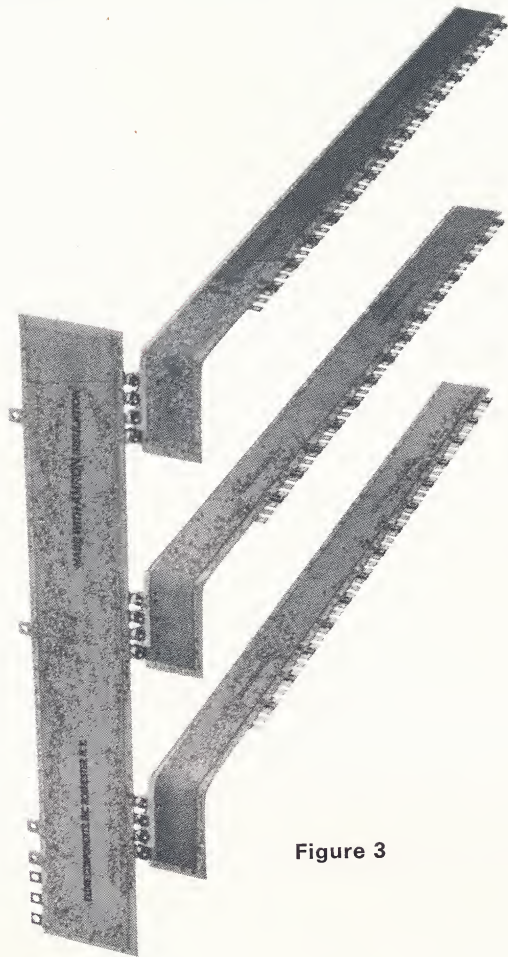


Figure 3

In most computer cabinets there are a group of card cages. Horizontal bus bars are incorporated into the design as mechanically dictated. As an example, the bus follows the horizontal plane and makes a right angle bend; the terminations break out directly into the vertical bus, making the bus system (see Figures 3 and 4).

Pig tails (see Figure 5) may be soldered or connected to the horizontal bus and then attached to the desired termination of the connector.

Figures 3 and 4 show conductors and grounds of the horizontal bus bar connected into the vertical bus conductor. Spacers and necessary mounting hardware are used as required.

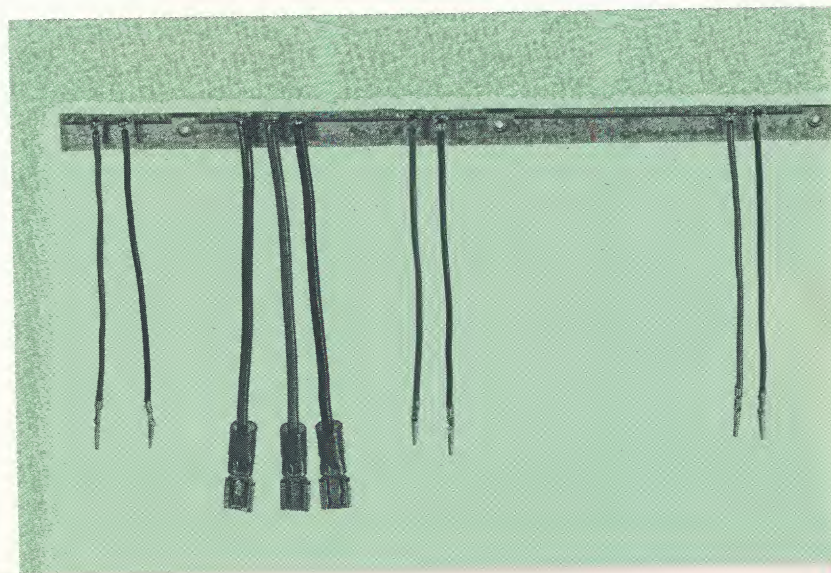


Figure 4

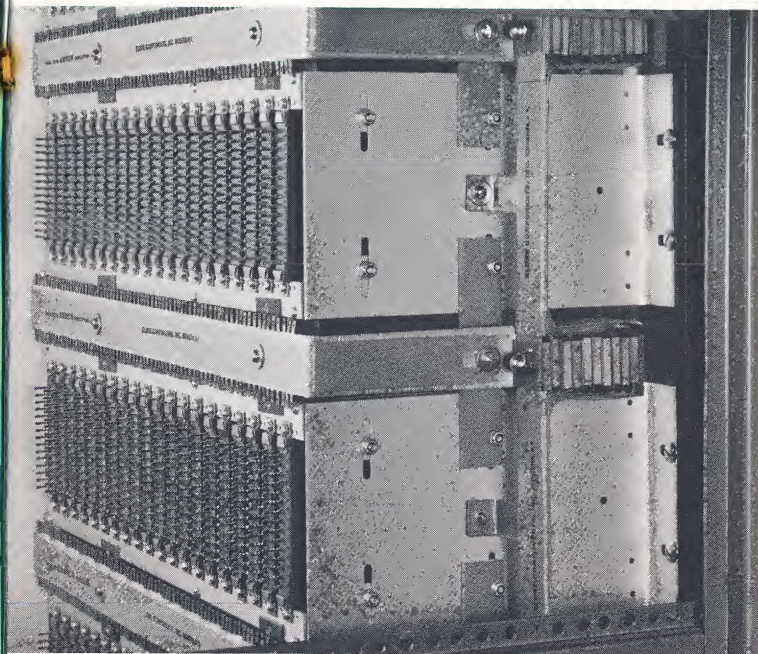


Figure 5

wire to flat-stock conversion chart

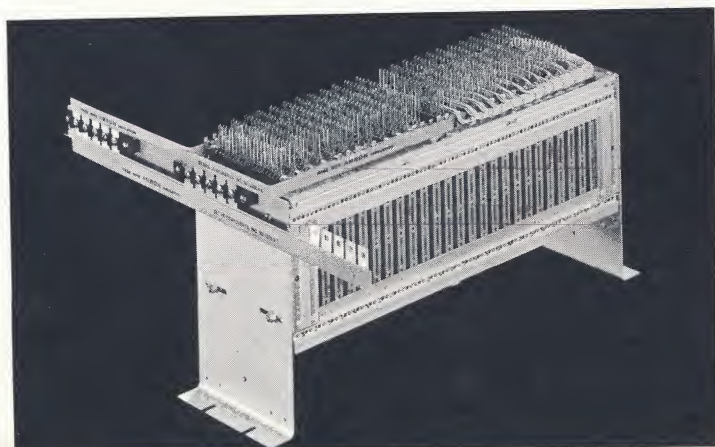
Wire Size	Diameter	Cir. Mils	Sq. Inches	Thick	Width
24	.0201	404	.000317	.005	.063
23	.0226	511	.000401	.005	.080
22	.0253	640	.000503	.005	.101
21	.0285	812	.000638	.005	.128
20	.0320	1,020	.000804	.005	.161
19	.0359	1,290	.00101	.005	.202
18	.0403	1,620	.00128	.005	.256
17	.0453	2,050	.00161	.005	.322
16	.0508	2,580	.00203	.005	.406
15	.0571	3,260	.00256	.005	.512
14	.0641	4,110	.00323	.005	.646
13	.0720	5,180	.00407	.005	.814
12	.0808	6,530	.00513	.010	.513
11	.0907	8,230	.00646	.010	.646
10	.1019	10,380	.00815	.010	.815
9	.1144	13,090	.01028	.015	.685
8	.1285	16,510	.01297	.015	.865
7	.1443	20,820	.01635	.020	.818
6	.1620	26,240	.02061	.025	.824
5	.1819	33,090	.02599	.030	.866
4	.2043	41,740	.03278	.035	.937
3	.2294	52,620	.04133	.045	.918

electrical characteristics

Bus bar systems are designed and manufactured to replace cables and harnesses used in electronic power distribution systems. In addition to mechanical design and packaging advantages, ELDRE bus bar systems also have advantages in their electrical characteristics.

In many applications—in fact, quite typically—the bus bar is used in pulse and digital systems. The very nature of the loads are ones which cause wide frequency bands of noise and disturbances to be generated and which, in turn, are coupled to adjacent harness wiring. A basic characteristic of the bus bar method of power distribution is the inherent means of minimizing either the radiated or the received disturbances. In addition, the basic design of the laminated bus offers very real advantages of shielding between conductors and shielding conductor pairs.

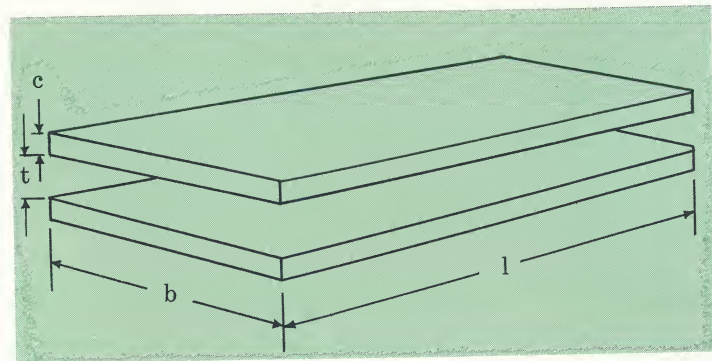
A few standard reference book electrical relations, which may be used as guides in considering the advantages of the ELDRE laminated bus bar, are presented in this section.



INDUCTANCE

The self-inductance of two parallel rectangular bars carrying current in opposite directions, and with the dimensions as shown in the sketch, is approximated by:

$$L = 0.01 \, l \left(2.303 \log_{10} \frac{2c + t}{b + c} + 1.5 \right) \text{ microhenries}$$



The above formula holds true only for adjacent conductors in the same circuit. It is, therefore, apparent that in order to obtain lowest possible L , the dielectric thickness between the two conductors should be held to a minimum, yet be consistent with good dielectric insulation and manufacturing practices. Also, the inductance can be minimized by providing for a wide conductor (dimension b in the sketch).

In designing the bus, care should be taken to make the length between the source and the connections to the load as short as possible. Nevertheless, the design approach of flat parallel conductors used in pairs should be employed throughout the complete distribution system for *lowest overall inductance*.

CAPACITANCE

Capacitance exists between conductors and between conductors and grounds. Such capacitance, usually small, is ordinarily of no importance in the case of low frequency currents, but can be important in circuits that have, or are susceptible to, high frequency disturbances.

To suppress the undesirable voltages and random noise, the design of the bus should develop the maximum allowable capacitance between adjacent conductors in the same circuit. This may be achieved by:

(1) keeping the thickness of the dielectric material as thin as possible consistent with good design and manufacturing practices.

(2) utilizing dielectric materials having a high K factor consistent with other electrical properties in the bus design and construction such as AMRON insulation which has a K factor of 3.4.

A formula for estimating the capacitance of a bus is:

$$C = \frac{0.224 \text{ KA (N-1)}}{d} \text{ picofarads}$$

K = dielectric constant of material between the conductors

A = area of one side of a conductor in square inches

d = thickness of dielectric in inches

N = number of conductors*

0.224 = a constant, when A is expressed in sq. in. (when area is expressed in sq. cm., the constant is 0.0885 instead of 0.224).

*Examples: N = 2 for a bus with 2 conductors, one for the outgoing conductor and the other for the return conductor.

N = 3 for a bus with 3 conductors, one between 2 others which are connected together.

RESISTANCE

To calculate the dc resistance at 20°C of a bus conductor circuit comprised of the outgoing feeder line and return, the following formula applies:

$$(1) R_{t1} = \frac{10.37}{A} \times 2l; \text{ ohms}$$

10.37 = resistance of 1 Cm/Ft. @ 20°C for A in circular mils and l in feet.

0.68×10^{-6} = resistance of 1 inch cube @ 20°C for A in square inches and l in inches.

A = cross sectional area of bus.

2l = total length of both conductors.

To determine the dc resistance of a bus conductor at temperatures other than 20°, the following formula applies:

$$(2) R_{t2} = R_{t1} [1 + \delta (t_2 - t_1)]; \text{ ohms}$$

R_{t1} = resistance at 20°C

δ = coefficient of electrical resistance per degrees centigrade rise over 20° = .00393

R_{t1} and R_{t2} are the conductor resistances at t_1 and t_2 respectively.

To calculate the maximum dc voltage drop in a bus conductor, the following formula applies.

$$(3) E_d = IR_{t2}; \text{ volts}$$

E_d = total voltage drop

I = max dc amps

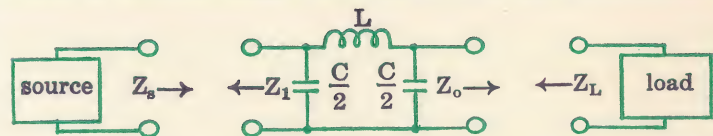
R_{t2} = resistance of bus at elevated temperature above 20°C.

The ac resistance increases with frequency and width of the conductor. Reasonable estimates of $\frac{R_{ac}}{R_{dc}}$ can be developed from the data presented on Page 7.

IMPEDANCE

In the design and construction of the laminated bus, consideration should be given to maintaining the impedance (Z) at the lowest possible value, consistent with good engineering and manufacturing practices.

The impedance characteristics of a bus bar system are rather complex. In addition, a bus bar system often consists of two or more laminated, molded assemblies. Nevertheless, it is convenient to consider the ELDRE Bus as a form of transfer device or transmission line. Assume that the bus is represented by a π section circuit with the following definitions:



Z_o = impedance of the bus and source (Z_s connected) as "seen" by the load; ohms.

L = self inductance of the particular conductors under consideration in the bus; henries.

C = capacitance between the particular conductors under consideration; farads.

Z_s = output impedance of the source; ohms.

Z_2 = input impedance of the load; ohms.

Then the line impedance presented to the load as a function of the frequency is:

$$Z_o(\omega) = \frac{Z_s \left(1 - \frac{\omega^2}{2 \omega_o^2}\right) + j \omega L}{\left(1 - \frac{\omega^2}{2 \omega_o^2}\right) + j \omega C Z_s \left(1 - \frac{\omega^2}{4 \omega_o^2}\right)} ; \text{ ohms}$$

$$\text{where } \omega_o^2 = \frac{1}{L C}$$

$$\omega = 2\pi f; f \text{ in cycles per second}$$

$$j = \sqrt{-1} \text{ imaginary operator}$$

If Z_2 is substituted for Z_s , Z_1 is determined and is the impedance that the source "sees" when connected to the line with the load connected at the other end.

Impedance conditions of interest to the designer who wants to get a "feel" for performance are presented in the chart below

as a function of the frequency ratio $\frac{\omega}{\omega_o}$		
$\left(\frac{\omega}{\omega_o}\right)^2$	$Z_o(\omega)$	$ Z_o(\omega) $
0	Z_s	$ Z_s $
2	$\frac{2 L}{Z_s C}$	$\left \frac{2 L}{Z_s C} \right $
4	$Z_s - j 2 \sqrt{\frac{L}{C}}$	$\left \sqrt{Z_s^2 + 4 \frac{L}{C}} \right $
∞	$-j 0$	$ 0 $

CONDUCTOR SIZE

For practical engineering reasons, a value of approximately 400 circular mils per ampere has been established as a base line for the design of a single conductor. This circular mil area should be increased by five percent per each additional conductor laminated into the bus assembly. The following formula is given for determining the minimum size of the conductors.

$$A = 400 I [1 + .05 (N-1)]; \text{ Cm}$$

A = area of conductor in circular mils

I = max dc current in amperes

N = number of conductors in bus assembly

To convert the circular mil area to square mils for establishing the conductor dimensions in thousandths of inches, multiply the circular mils by 0.785. See Conversion Chart page 11.

GROUNDING

The ground return conductor should be equal in size and circular mil area to its corresponding line bus. A few advantages of separate ground return are:

- (1) greater area for cooling, to minimize the voltage drop due to temperature rise.
- (2) common-mode and inter-coupling effects are drastically reduced.
- (3) advantageous shielding between line levels can be obtained.

pricing of buses

Prices of bus bar assemblies vary with quantities ordered, anticipated annual requirements, fabrications, types and number of terminals, dimensions, tolerances, etc. Many off-the-shelf ELDRE buses are available—anyone of which could be the practical solution for your application.

The cost—no more than for manufacturing, verification, and installation of ordinary cable and wiring circuits—and in most cases, just a few of the many advantages of the ELDRE Bus have reduced costs. The bonus you receive with the ELDRE Bus is in the reliability and performance of the product—at *no extra cost to you*.

summary

Your requirements for power distribution are in capable hands at ELDRE Components. This new concept—the laminated bus bar—has already found wide application in data processing, commercial and military electronic control and communication systems. Advantages in fabrication include design flexibility, simplification of assembly, reduction in inventory and packaging—and in performance, minimizing noise and disturbances. Why not investigate these advantages—ELDRE Components are prepared to discuss design, development and production of new and better products for your company.

Experience and skill are offered by ELDRE Components to satisfy your needs for precision and reliability.

Amron insulation

AMRON insulation, a product of ELDRE Components, Inc., is made of a composite of a web, film, web construction. The outside webs are a non-woven polyester fiber bonded to a polyester film and impregnated with a vinyl resin.

The film, being sealed or enclosed between the webs, does not degrade at elevated temperatures as an exposed film would. The web affords the property of protection as well as better thermal stability due to its higher degree of orientation.

AMRON has a wide range of desirable advantages. It has good thermal stability and has low moisture sensitivity, providing a low leakage characteristic. There is high physical strength and good chemical resistance in this composite. The dielectric strength is relatively high. The dielectric constant of AMRON is 3.4.

Amron insulation properties

AMRON Number	Material Thickness	Dielectric Strength
#3	.0055"	800 VDC
#4	.006"	1000 VDC
#5	.007"	1500 VDC
#6	.008"	2000 VDC



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